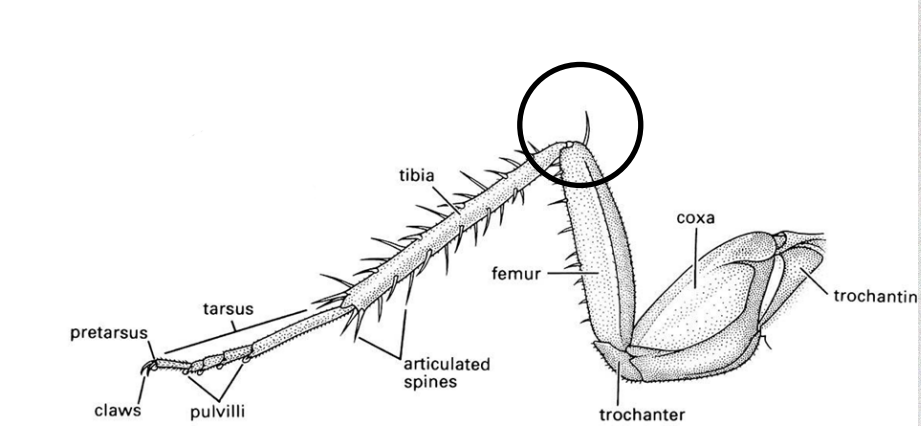
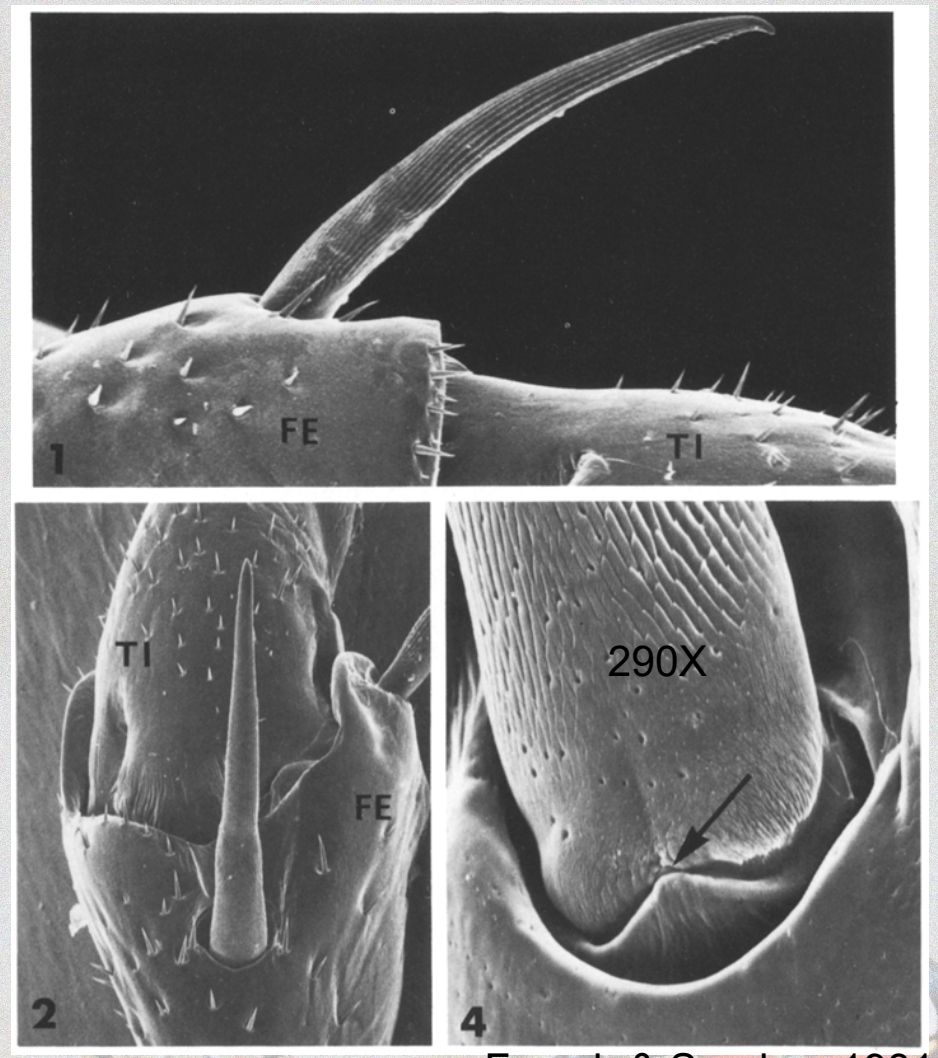
Cockroach Sensory Nerve Practical

Mechanoreceptors - Rate code - Receptive fields – Adaptation - Habituation





French & Sanders 1981

Cockroach Sensory Nerve Practical

Bring the instructions to the lab

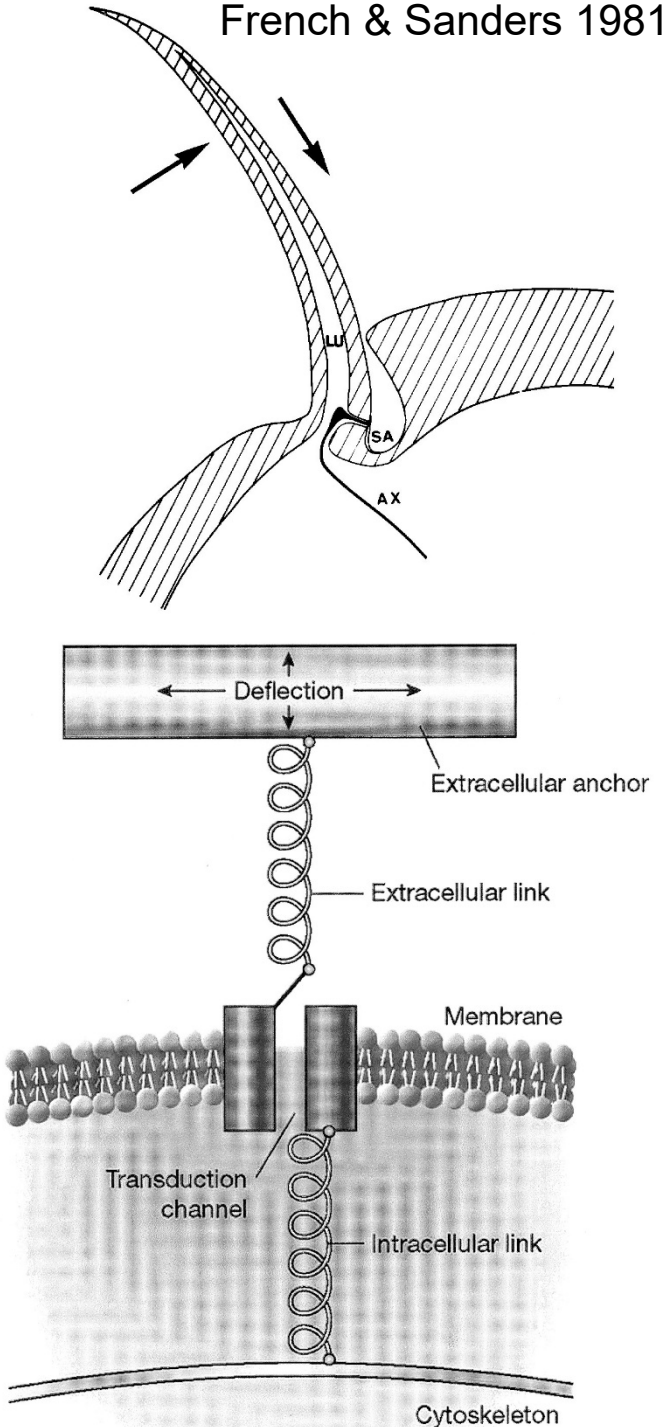
Concepts

- Mechanoreceptors
- Electrophysiology
- Sensory adaptation (vs) habituation
- Receptive fields

Mechanotransduction

- Tripping the ion channel to change receptor potential:
  - Direct force on the lipid bilayer of the membrane around the channel changes channel conformation
  - Tethers (i.e. in haircells) affect channel conformation
- High speed response (no second messengers): latency ~ tens of μs → 1000 times faster than photoreceptors

French & Sanders 1981



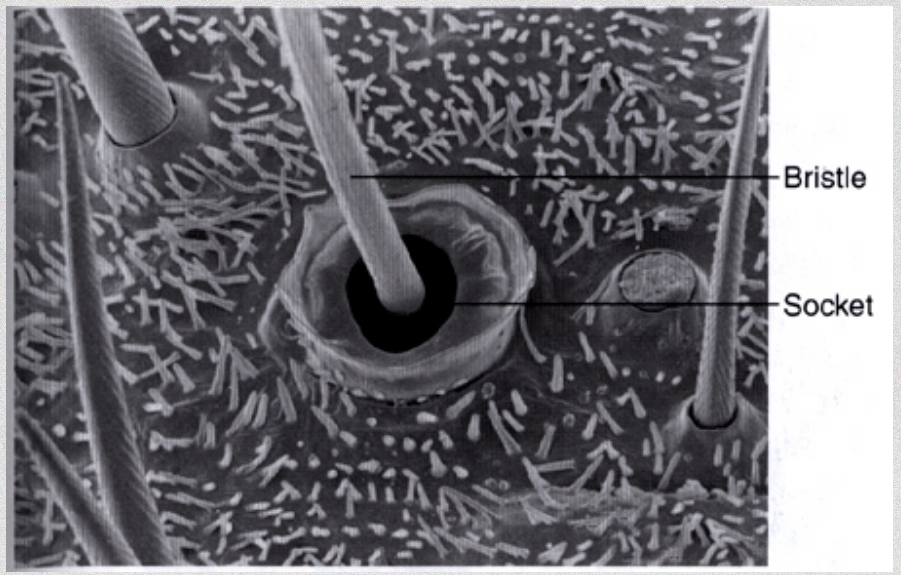
Mechanotransduction - stimuli

- External stimuli: touch, pressure, vibration, water currents and sound
  - Ear, somatosensory system, equilibrium organs (gravity and acceleration)
- Internal stimuli: contraction of muscles, limb flexion, pressure on blood vessels, osmolarity
  - Proprioception

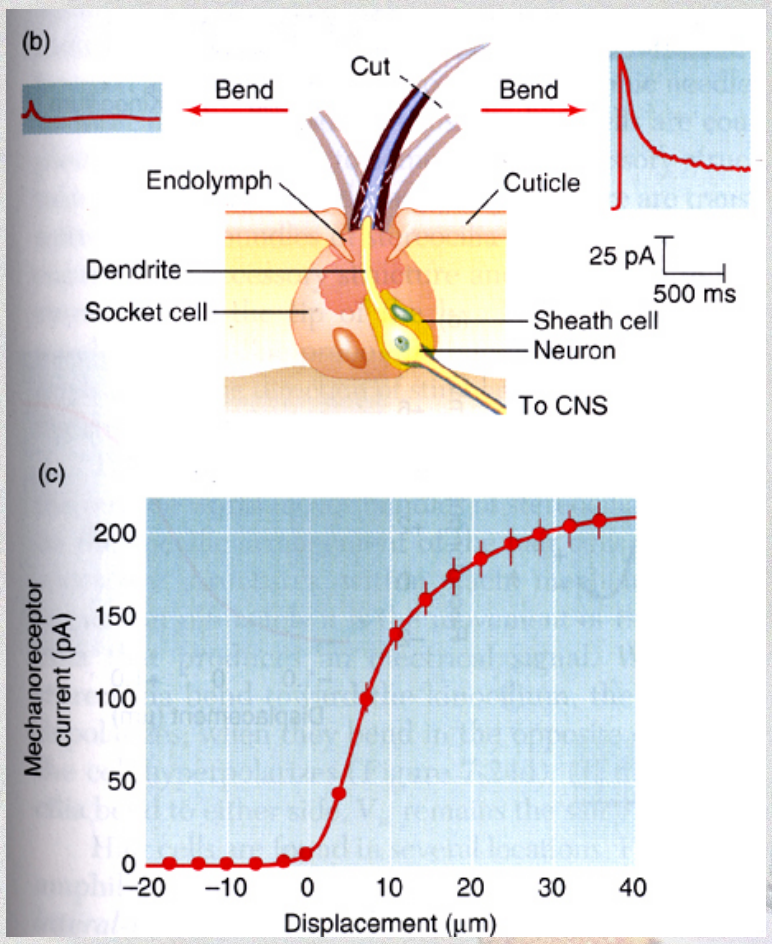
Mechanotransduction

Neural signals - insect bristle

Cricket hair



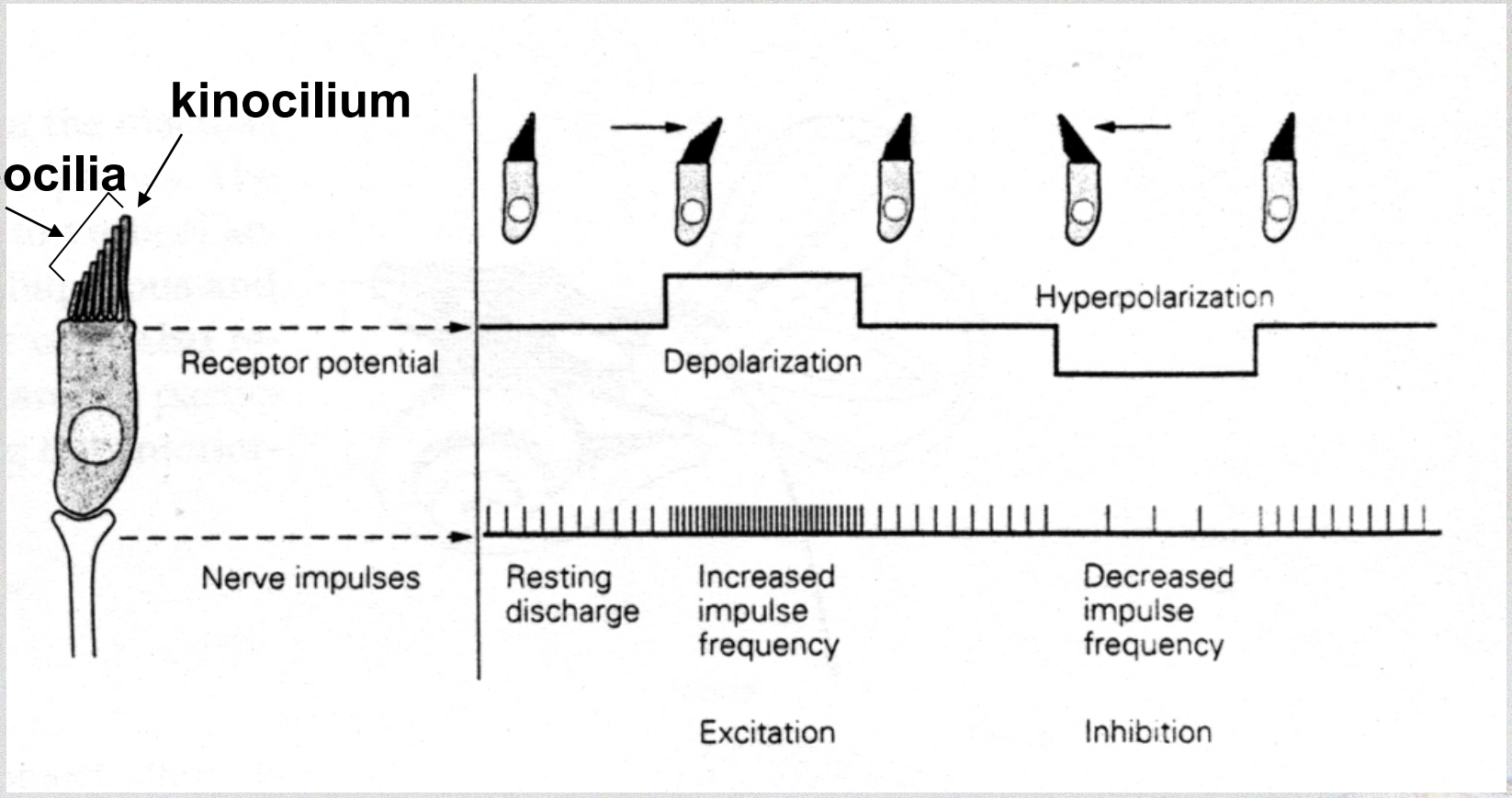
Drosophila bristle



Directional response

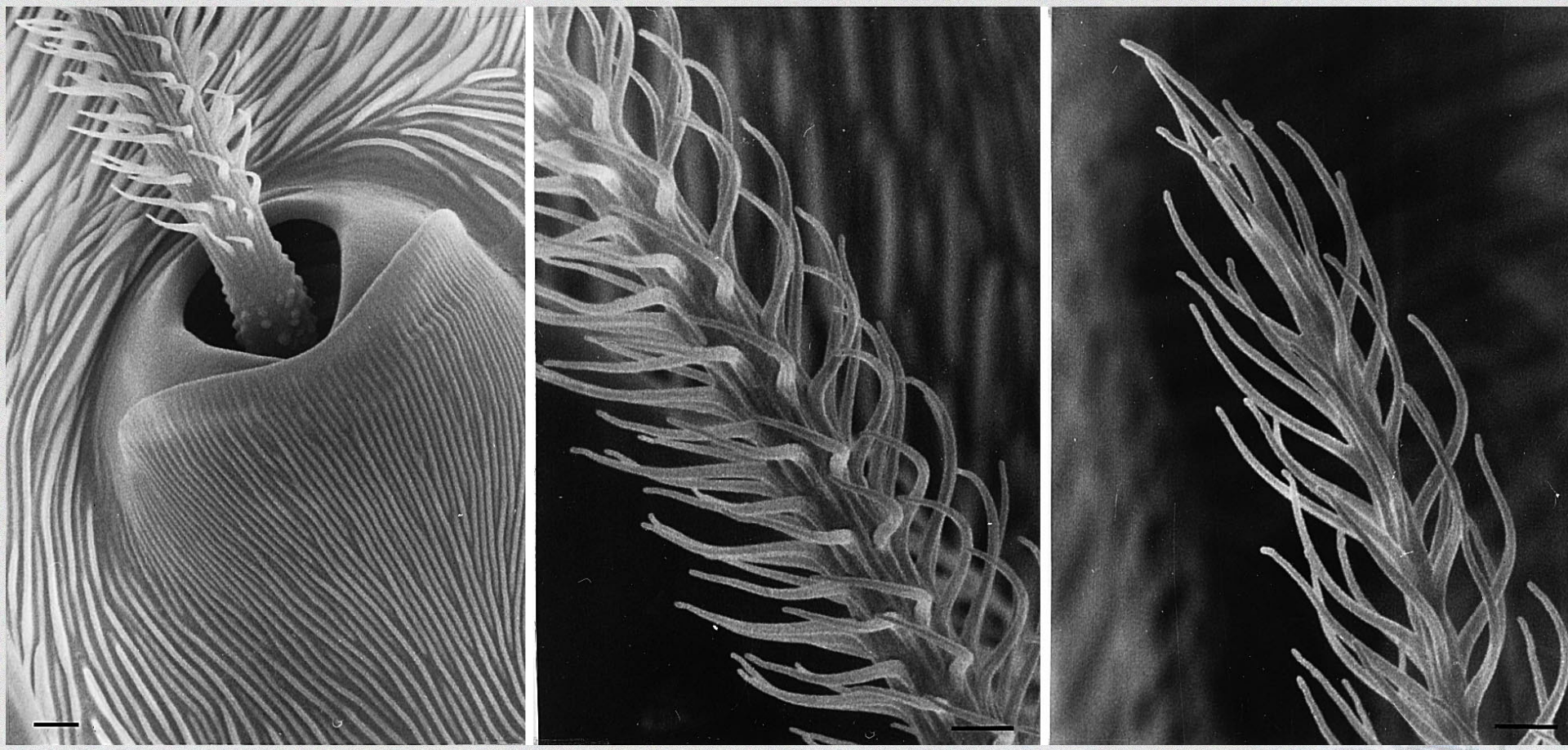
Mechanotransduction

Neural signals of hair cells



Movement required by hair cells: 0.3nm! = 1000 times less then wavelength of UV light

Scanning electron micrographs of a spider hair shaft

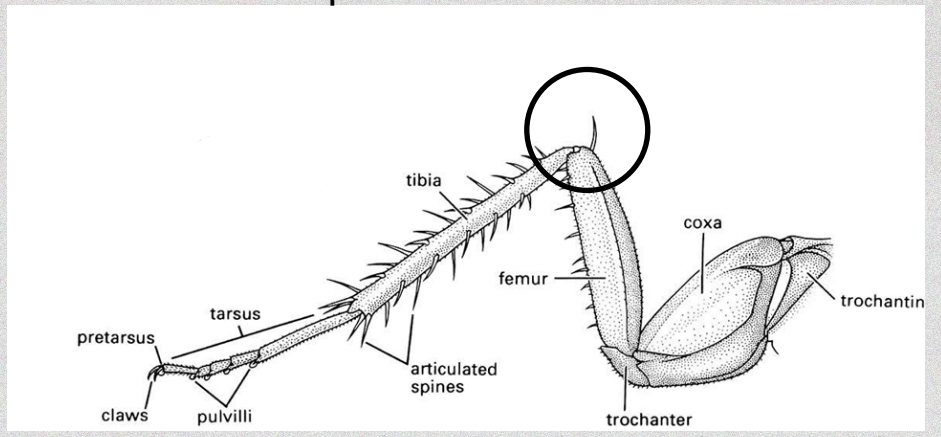


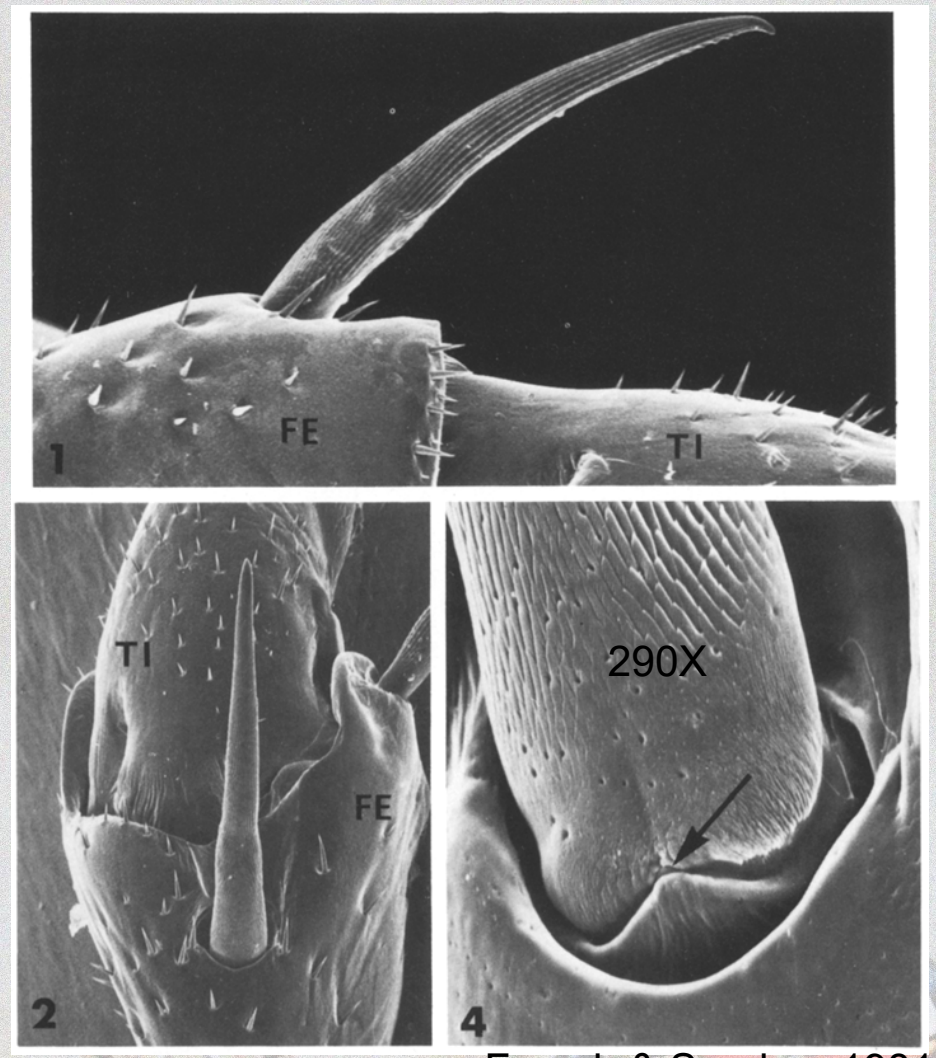
Base **Middle** **Tip**

Barth Naturwissenschaften (2000)

Cockroach Sensory Nerve Practical

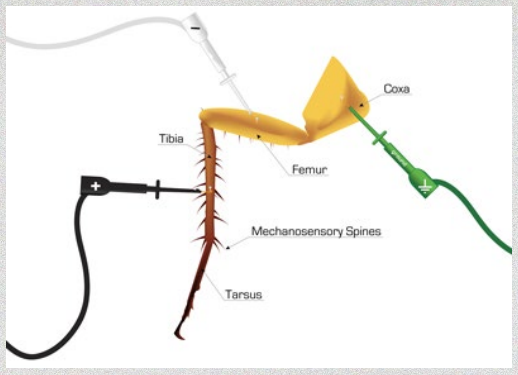
- Differential recordings from sensory nerve cord
- Electrical signals generated by the axons
- Action potentials

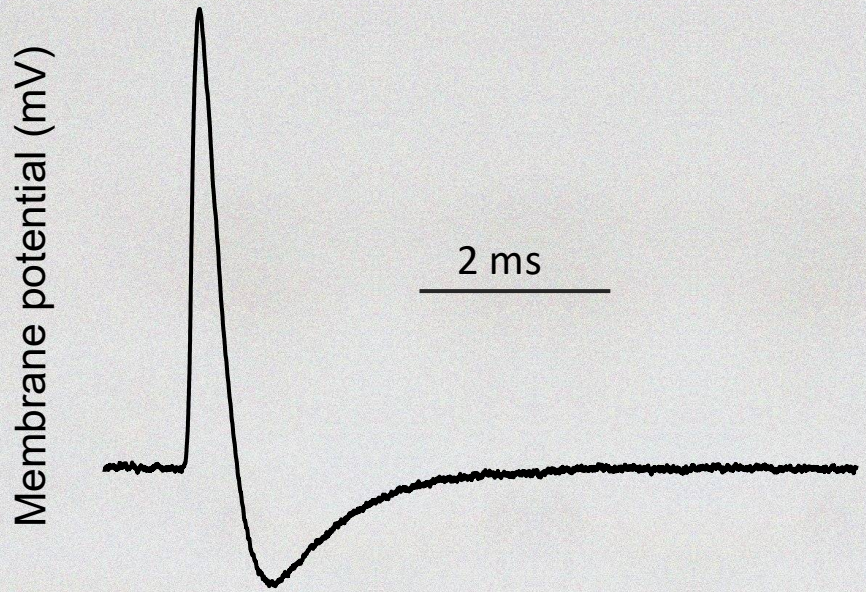


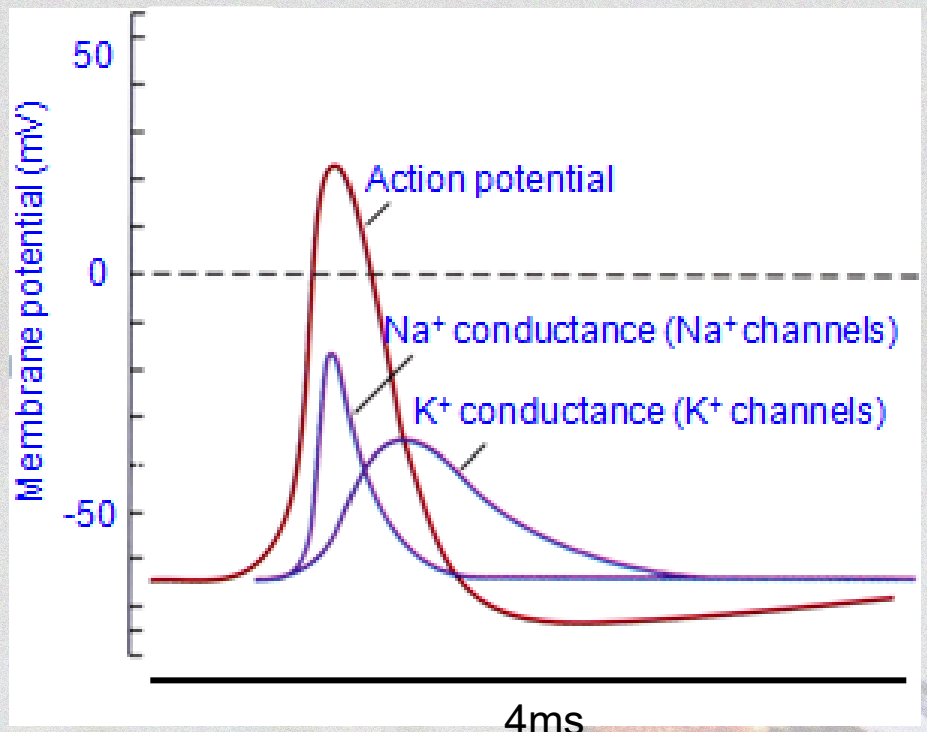


French & Sanders 1981

Neural spikes







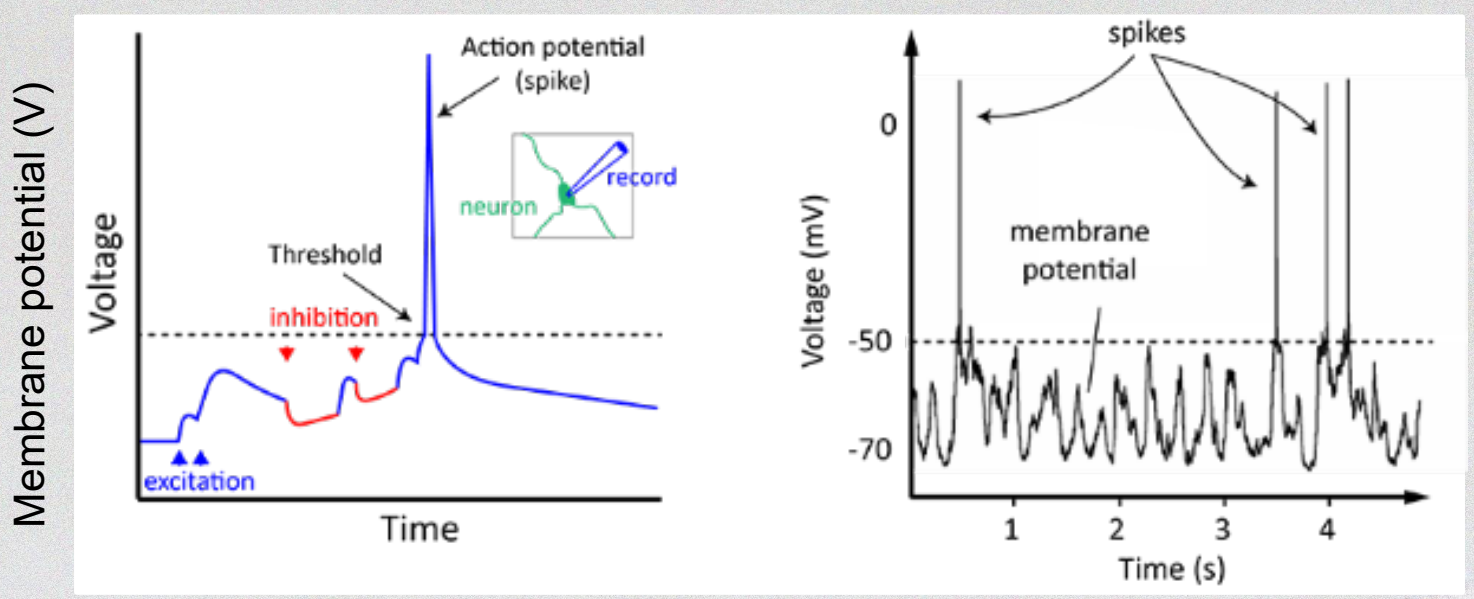
https://dundeemedstudentnotes.wordpress.com/2012/04/06/action-potentials/

Intracellular recordings from nerve fibres

Rate Coding of Sensory Inputs

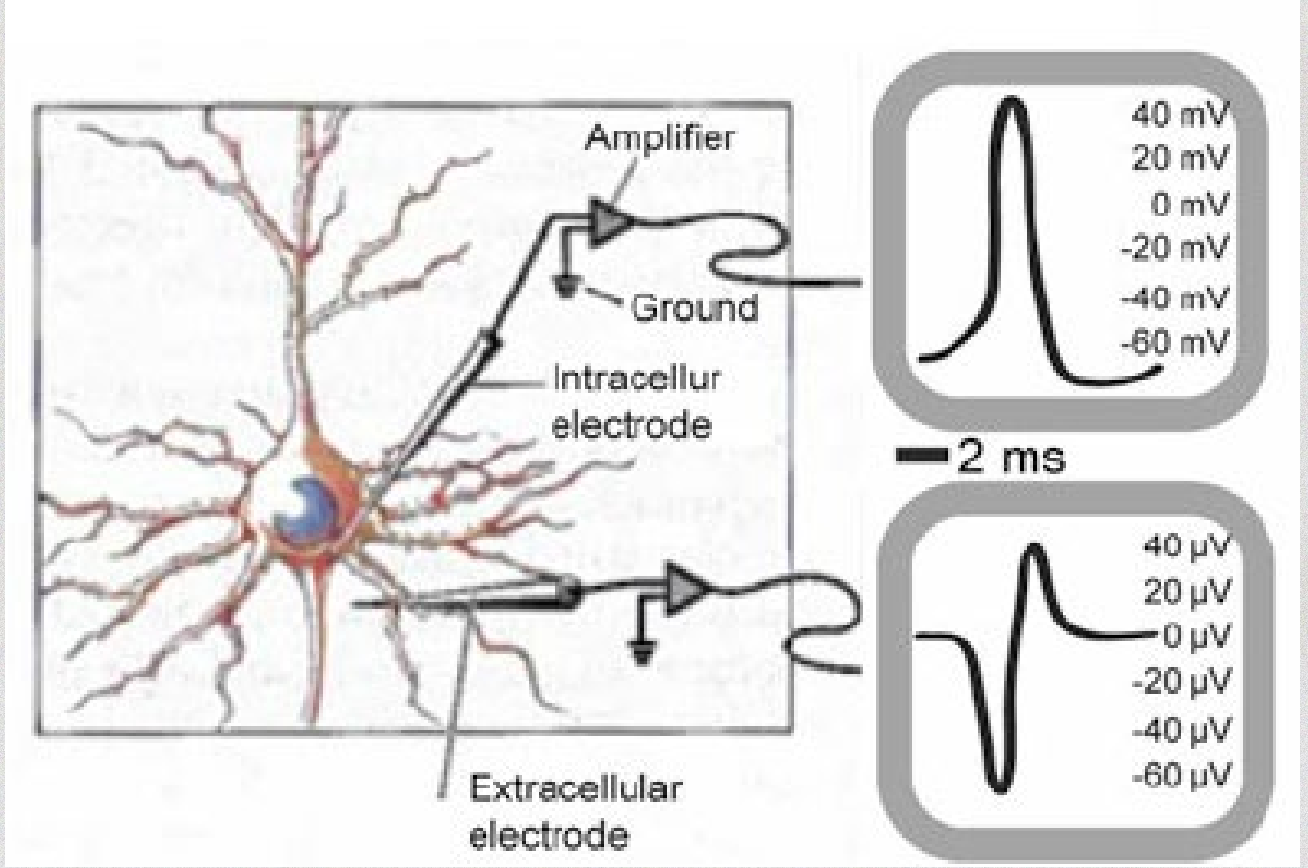
What part of the signal carries the information?

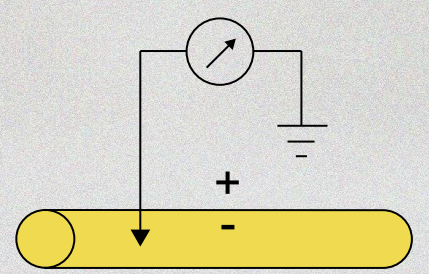
Intracellular recording

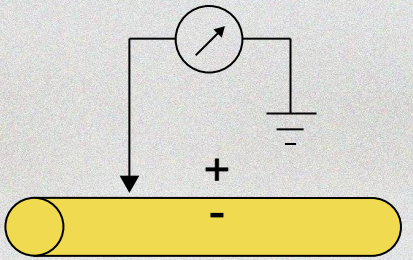


(Image: Alan Woodruff / QBI)

Intra- vs extracellular recordings: why are the potentials reversed and why is the size and shape so different?



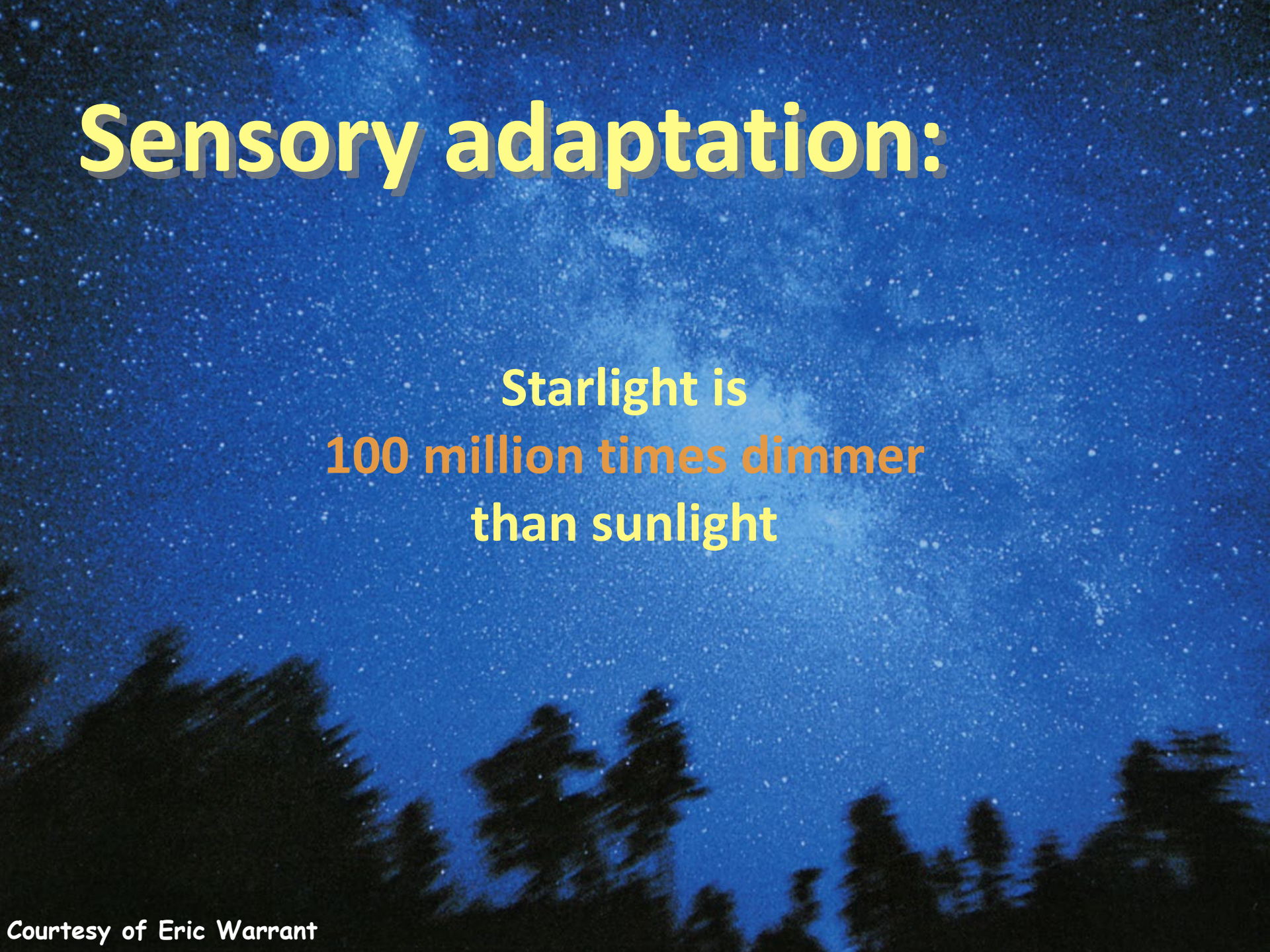




(Image: Claus Mathitesen

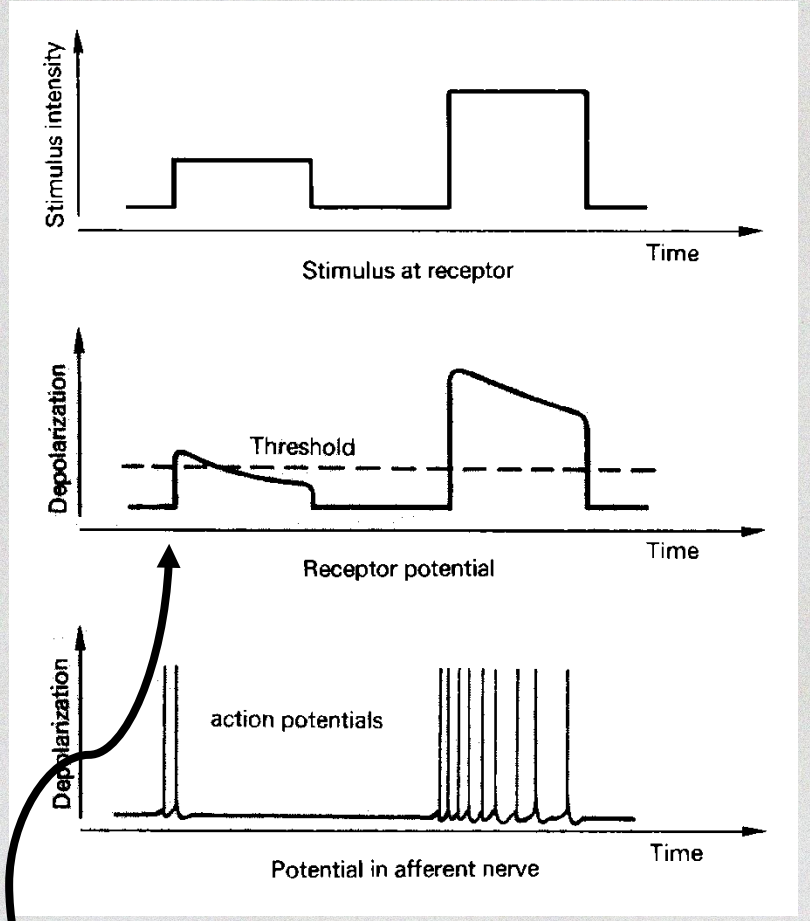
Sensory adaptation:

Starlight is
100 million times dimmer
than sunlight

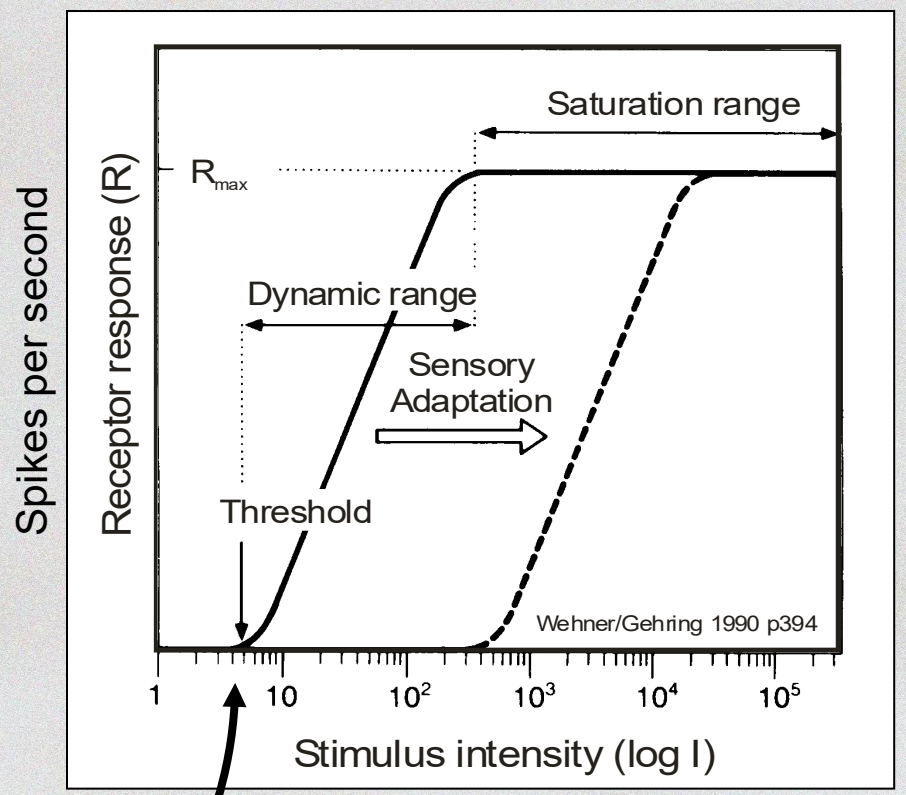


Courtesy of Eric Warrant

Sensory adaptation allows sensory system to adapt to constant stimuli



Tuning functions / sensitivity function

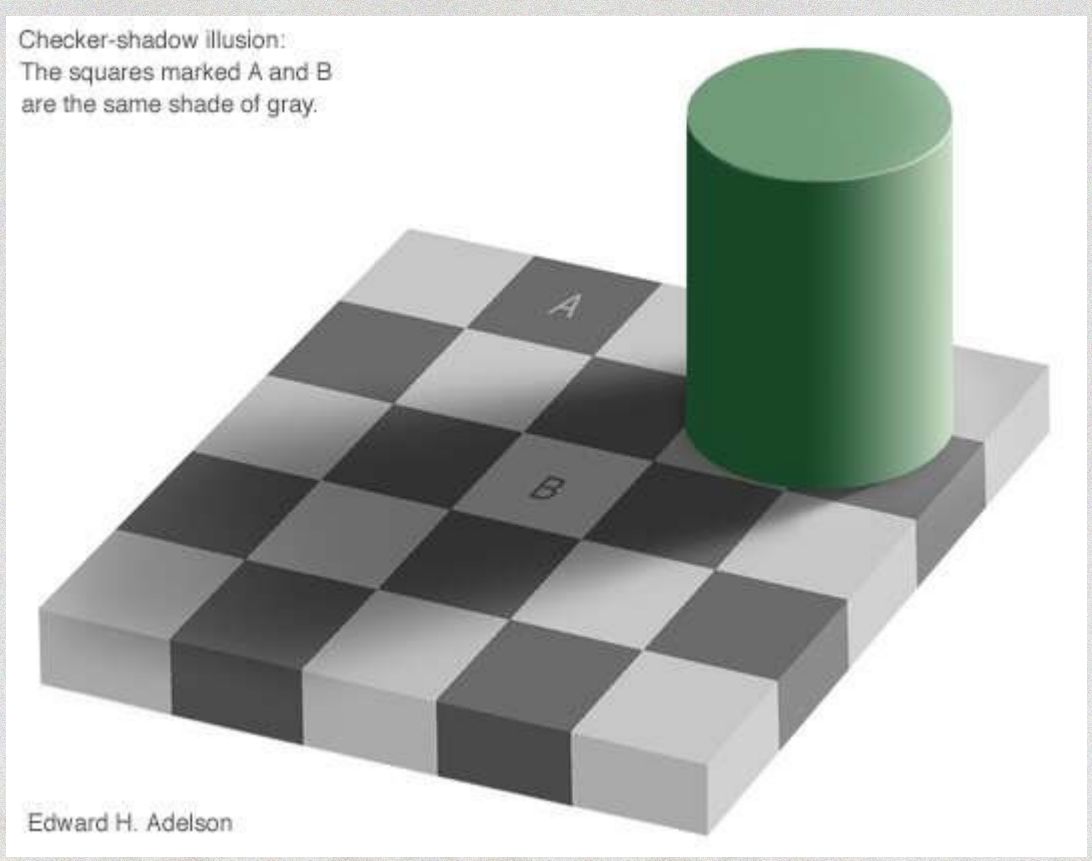


Receptor characteristic:
Threshold
Dynamic or working range

Example threshold sensitivities:
1 photon; 1 molecule; 0.1 nm leg deflection

Sensory adaptation: contrast is the key

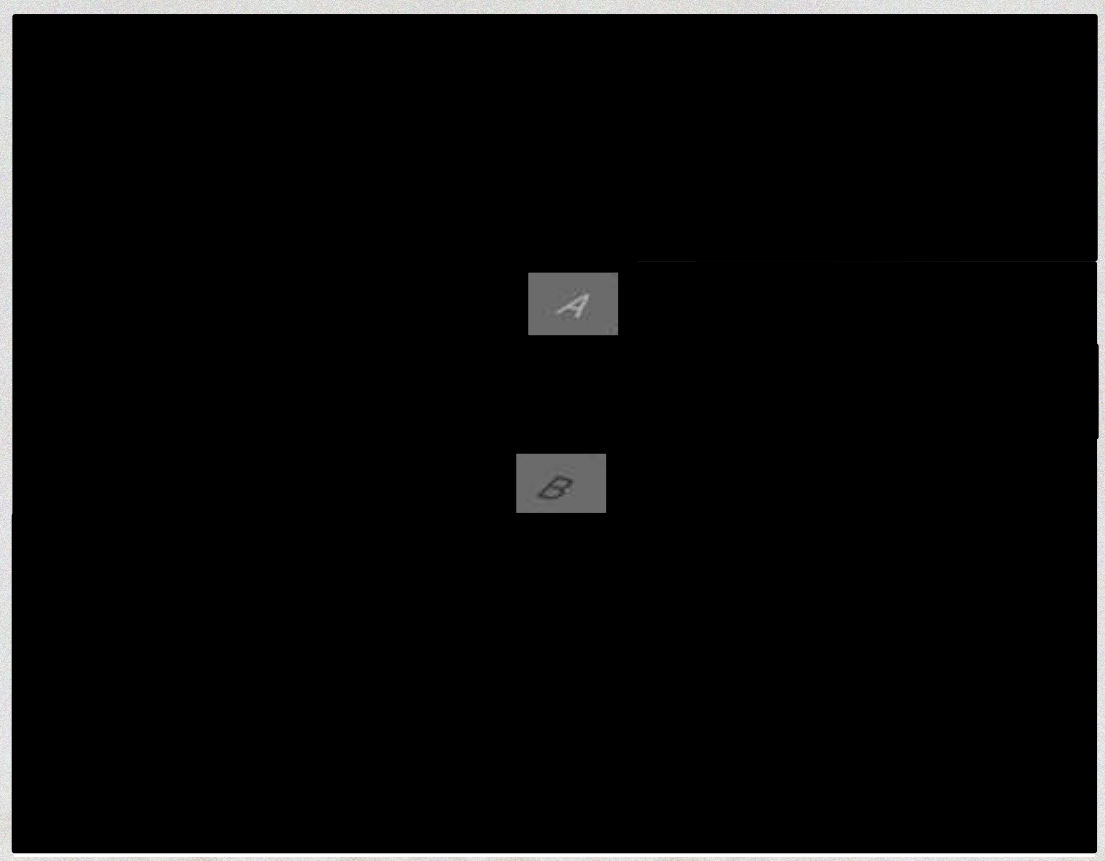
Because of their strong adaptation mechanisms, sensory systems are designed to detect contrast, not absolute values!



Local contrast and the shadow largely determine our perception of "brightness"

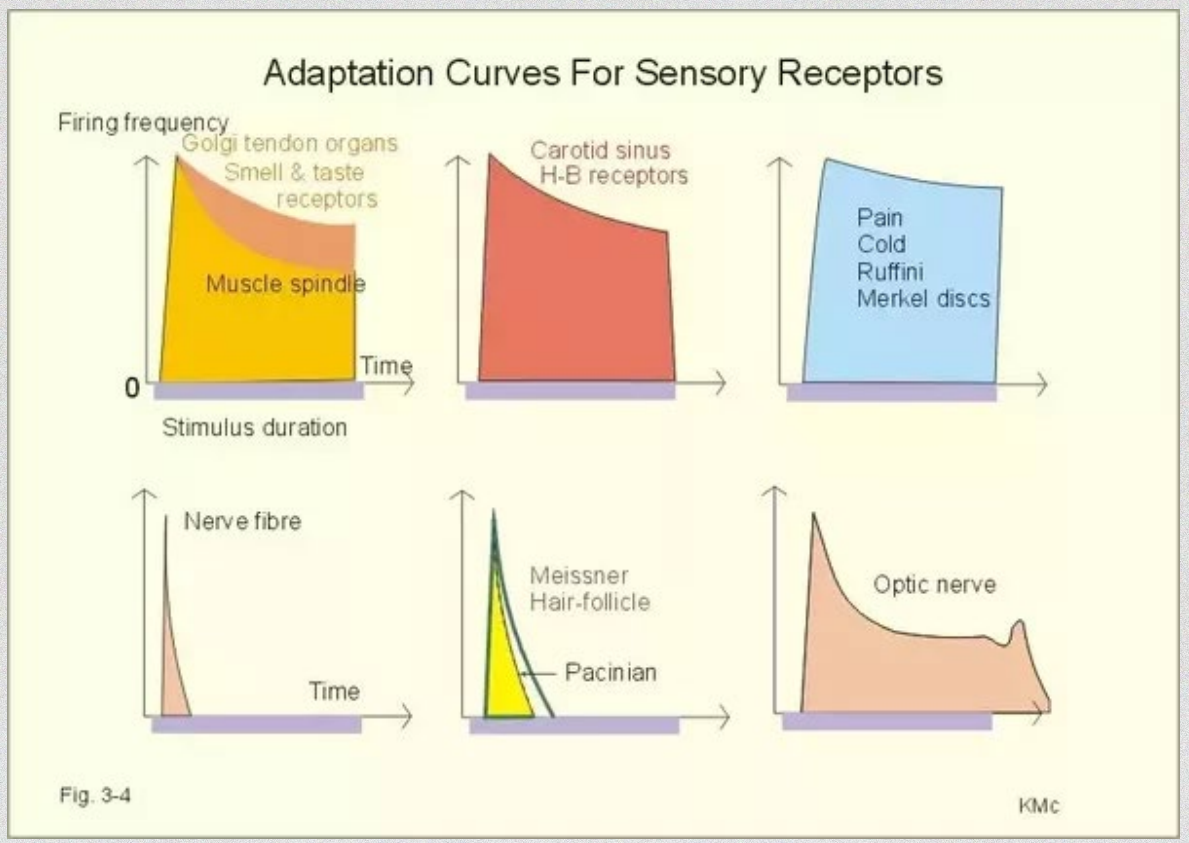
Sensory adaptation: contrast is the key

Because of their strong adaptation mechanisms, sensory systems are designed to detect contrast, not absolute values!



Local contrast and the shadow largely determine our perception of "brightness"

Adaptation properties of different sensory receptors



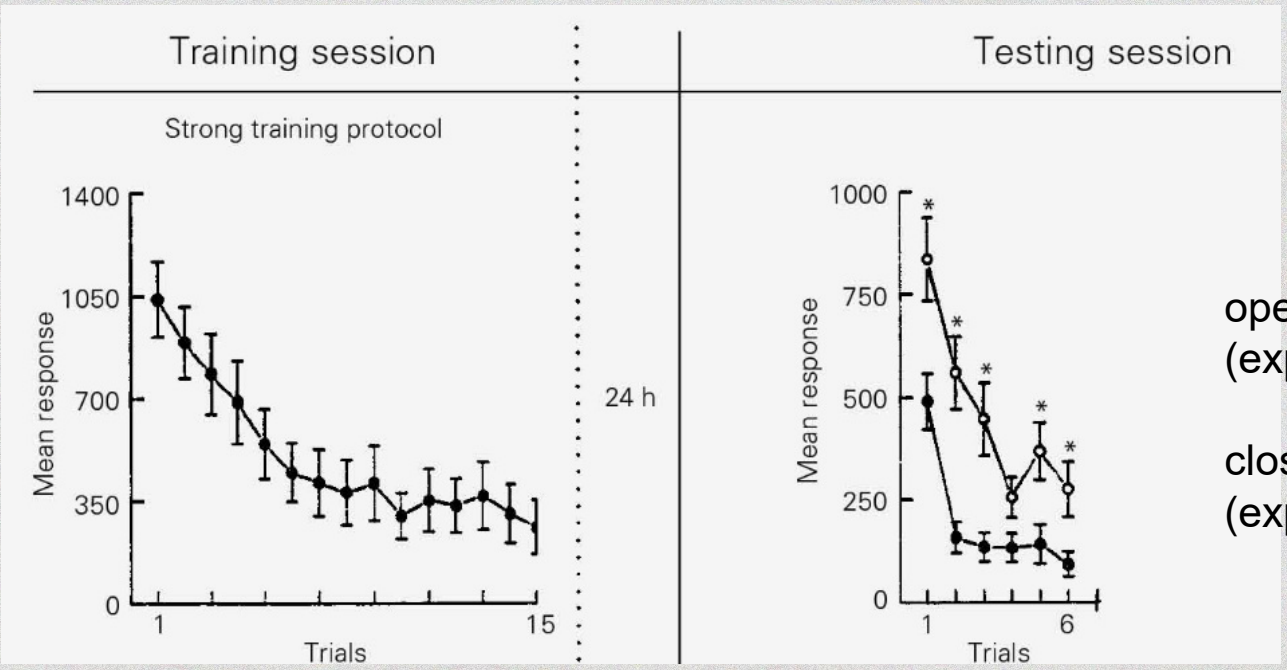
- Different neurons have different adaptation profiles
- Adaptation is fully reversible after period of inactivity

http://www.zuniv.net

Habituation – a behavioural concept

(however a neural circuit can also be said to habituate).

Response strength to a visual threat



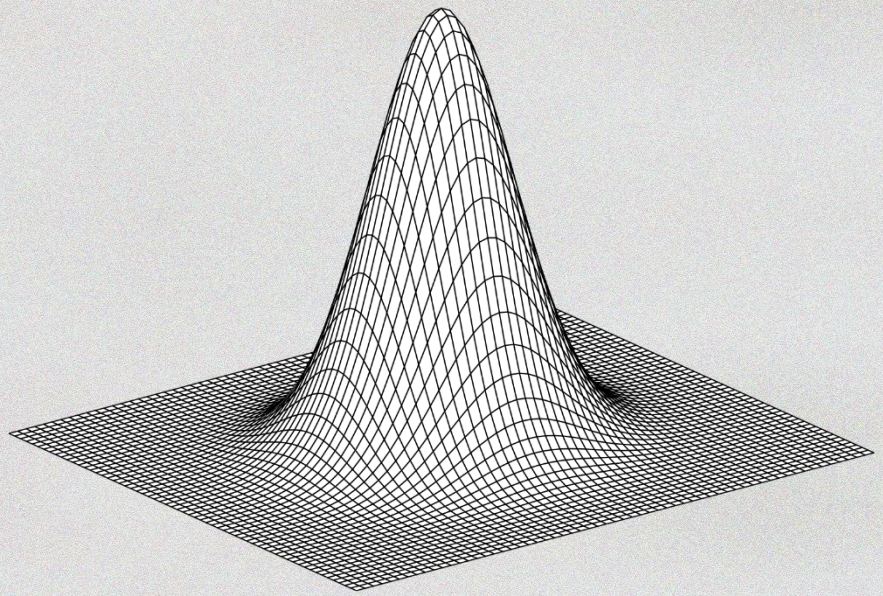
open circles: Control
(exposed for the first time)

closed circles: Test group
(exposed for a second time)

- Main criteria for habituation:
- Incremental change in response strength
- Stimulus specific
- Not fatigue (sensory or motor)
- Gradual recovery

- Dishabituation
- Sensitisation
- Long term vs short term habituation (involves the creation of new memories (>-24h)

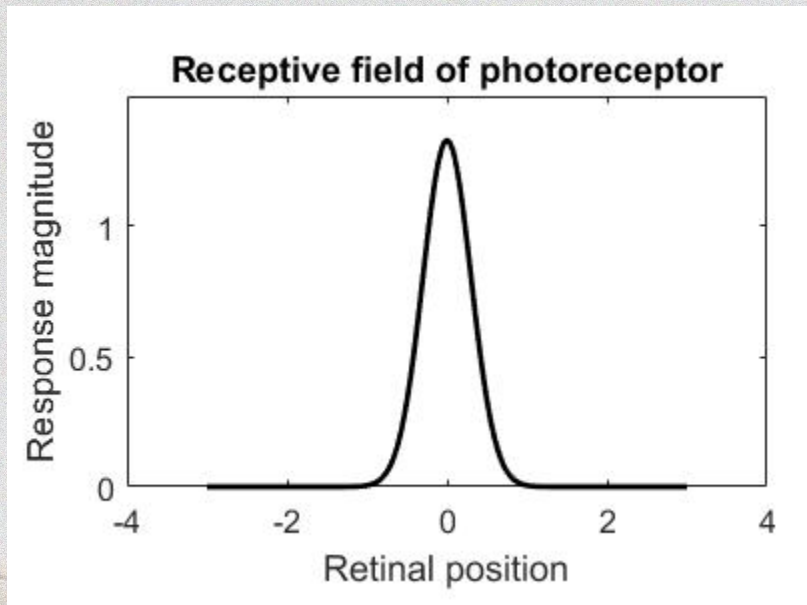
Receptive fields



A receptive field is the portion of sensory space in which the presence of a stimulus can modify a neuron's response

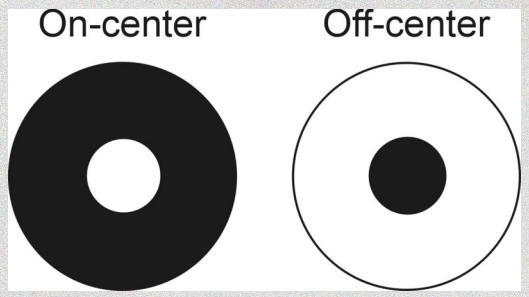
The sensory space can be:

- a patch of visual or auditory space
- a patch of skin
- tuning properties
  - Chain length of **odorant** for olfactory neurons
  - Frequency/temporal tuning of auditory neurons
  - A hair



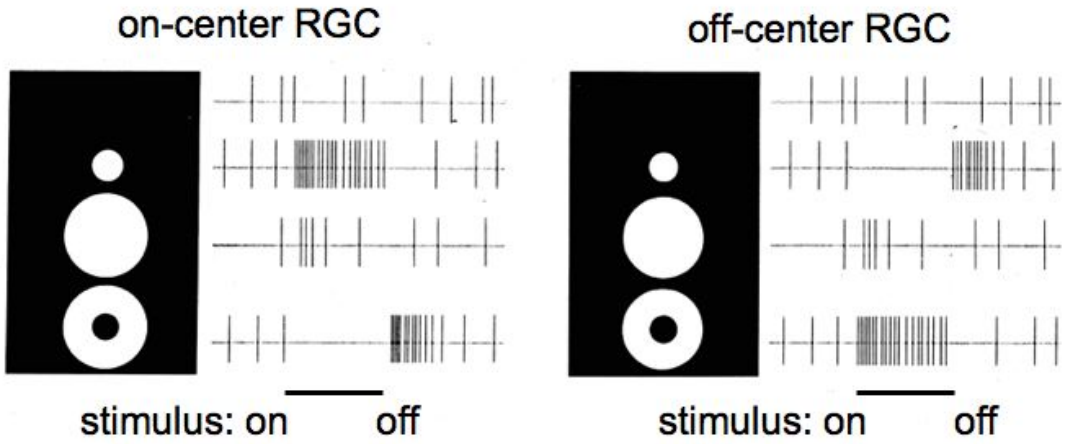
Receptive fields

centre-surround retinal ganglion cells

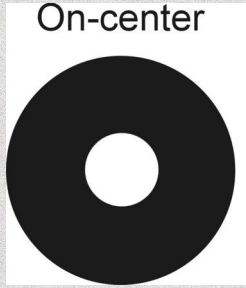


On-off retinal ganglion cells

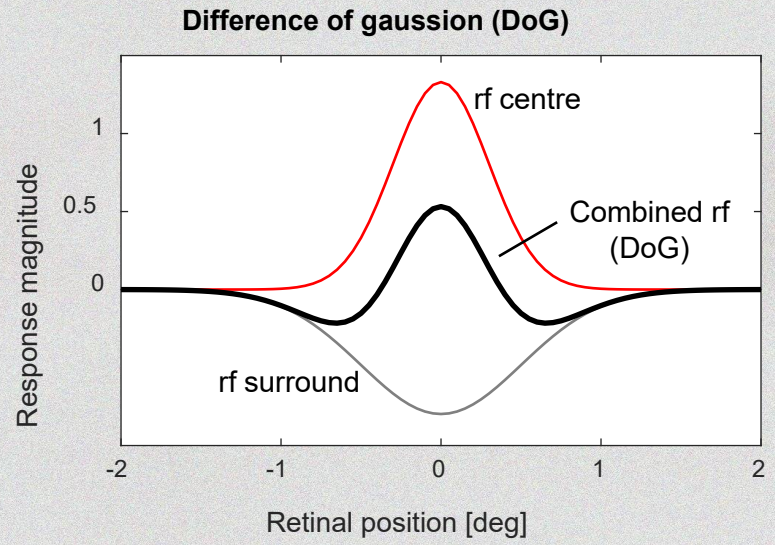
Stimulating on or off centre On-off retinal ganglion cells



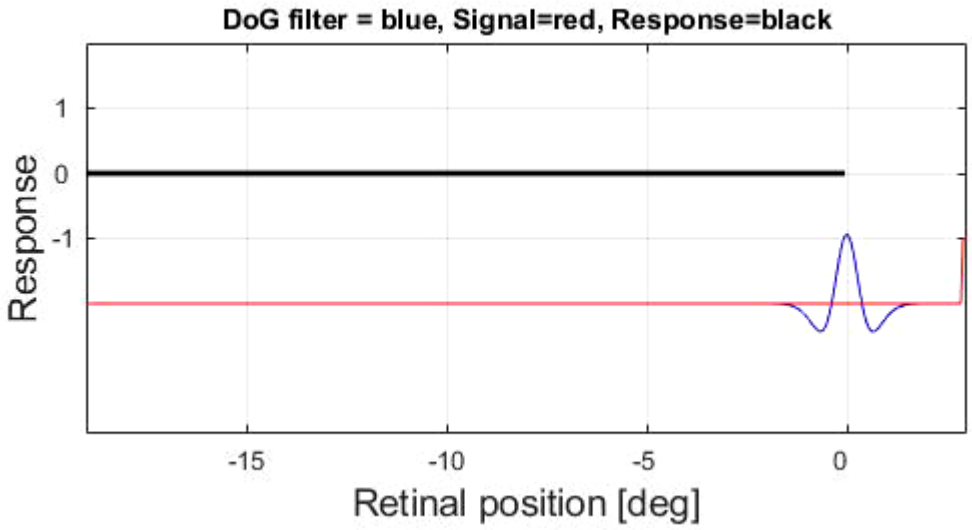
Receptive fields – functional consequences of centre surround



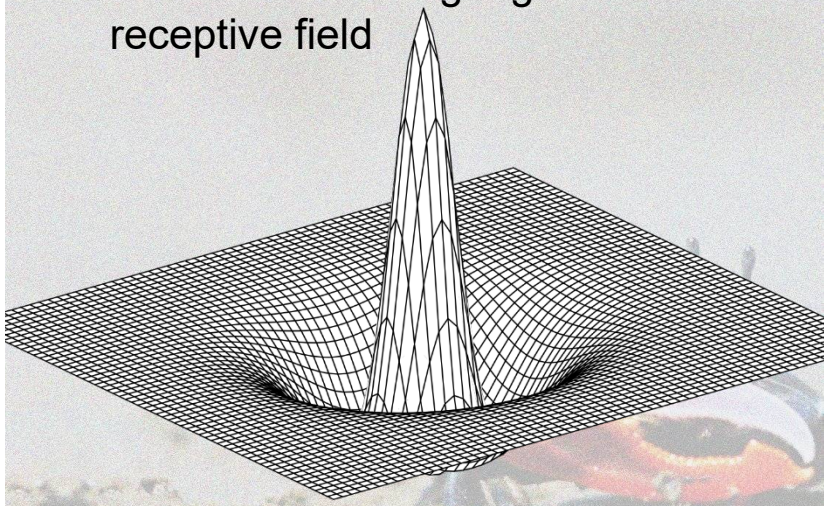
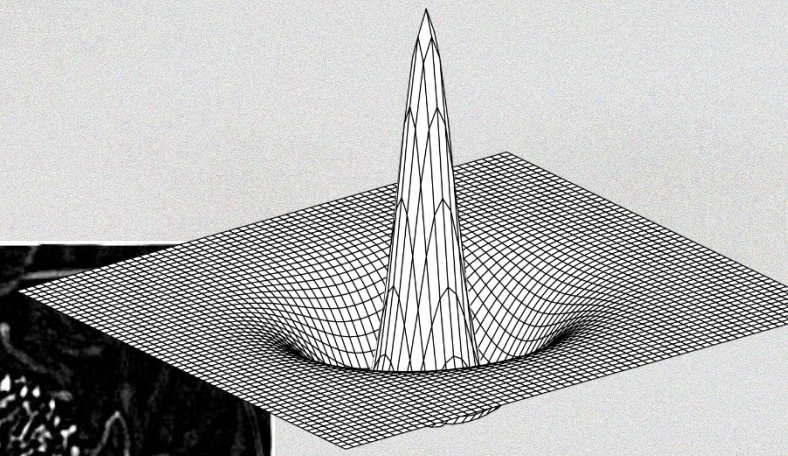
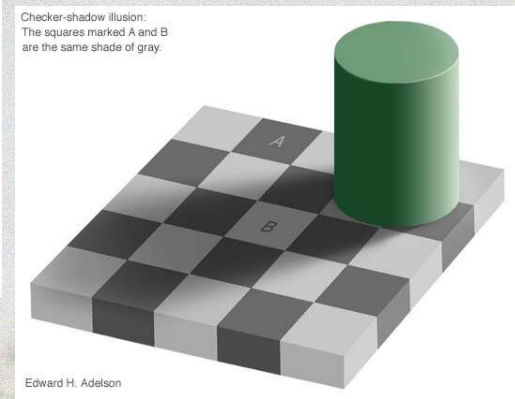
Centre-surround receptive fields can be modelled as a difference of Gaussians (DoG)



Example of how a centre-surround receptive field filters a visual input (in 1-dimension only)



On-centre retinal ganglion cell receptive field



Receptive fields: Neural images